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Male Release Call Characteristics of Japanese Toads

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ABSTRACT Variation in release call parameters was analyzed in relation to body temperature and body size in Japanese toads, *Bufo j. japonicus*, *B. j. formosus* and *B. gargarizans miyakonis*. Fundamental frequency shows high individual variation and has no correlation to varying body temperatures, but the frequency is predicted to decrease with the increment of body size. Note duration is more affected by body temperature than by body size, and is predicted to be shortened under higher temperature conditions. Note repetition rate correlates to both body temperature and body size and frequency of notes is predicted to increase in smaller individuals or under higher temperature conditions. Release call characteristics of Japanese toads are discussed in comparison with those of the American toads of the *B. americanus* group.

KEY WORDS *Bufo japonicus*/ *Bufo bufo* complex/ release call/ acoustics/ body size

Three known species of Japanese toads are members of the *Bufo bufo* complex and are close relatives of the European common toad, *Bufo b. bufo* (Matsui, 1984). This complex contains many forms (Matsui, 1980, MS) and is characterized by the absence of the external vocal sac. Hitherto, only *B. b. bufo* has been acoustically studied (Schneider, 1966; Flindt and Hemmer, 1968; Heusser, 1970) and it is indicated that calls are only rudimentarily developed in this species (Heusser, 1969). Dissimilar to cases in members of other species groups of toads, it is very hard to record mating calls (=advertisement calls: Wells, 1978) of toads of the *Bufo bufo* complex (Heusser, 1969, 1970; Matsui, unpublished), and collection of mating calls for the Japanese forms are now under way. By contrast, as in many other anurans, it is very easy to record release calls or warning vibrations of toads in the laboratory (Blair, 1947). Although mating call characteristics are regarded as taxonomically important in anuran amphibians (Blair, 1962) and detailed studies have been made for many toad species (e.g. Zweifel, 1968; Nevo and Schneider, 1976), release call traits also have been shown to offer clues for estimating phylogenetic relationships among some toad species (Brown and Littlejohn, 1972). Characteristics of release calls are known to vary according to the environmental conditions and body size of toads (Brown and Littlejohn, 1972), but no detailed analysis has hitherto been made on toads of the *Bufo bufo* complex. Therefore, relationships of temperature and size to release call parameters are analyzed in two species of the Japanese toads, *Bufo japonicus* (*j. japonicus* and *j. formosus*) and *B. gargarizans miyakonis*.

Materials and Methods

Brown and Littlejohn (1972) discriminated release chirp and release vibration as two components of release calls, but usually the former component alone is simply referred to "release call" by many authors (e.g., Capranica, 1968; Wells, 1978). I also regarded the first component as a release call. All recordings were made in the laboratory using either an open-reel tape recorder (Sony TC 5550–2) at a speed of 19 cm/sec or a cassette tape recorder (Sony TC-D5) at a speed of 4.75 cm/sec with external microphones (Victor MU-510 or Sony ECM-23F). Each male toad was held near the microphone and calls were elicited by pressing the back and sides of the animal with the fingers. Analyses of recorded calls were made using sonagraphs (Kay 7029A and 7800). Measured call parameters are fundamental frequency (FF), note duration (ND) and note repetition rate (NR=number of notes per second). To determine relationships of body temperature and call parameters, three males of *B. japonicus formosus* (from Iwakura, Kyoto (Population 61 in Matsui, 1984), N=1; Kuramayama, Kyoto (Pop. 60), N=2; Nogo Hakusan (Pop. 55), N=1), a male of *B. j. japonicus* (from Yakushima, (Pop. 96)) and a male of *B. gargarizans miyakonis* (from Miyakojima, (Pop. 97)) were subjected to various temperature conditions. After the body temperature (BT) was assumed to be stabilized, cloacal temperatures were recorded immediately before and after the recordings of release calls with a thin mercury thermometer. The mean value of these two temperatures was used for the subsequent statistical analyses. For estimating relationships between body size and call parameters, 30 individuals of *B. j. japonicus* in various body size (115.0–140.5 mm in snout-vent length (SVL)) from Megijima and Ogijima, Takamatsu, Kagawa (Pop. 81) were used. SVL measurement was taken by a dial caliper for a toad gently pressed on a board. Immediately before and after calls were recorded, BT was also measured by the method described above.

Results

Sonagrams of typical release calls of *B. j. formosus* from Kuramayama, Kyoto, *B. j. japonicus* from Takamatsu and Yakushima, and *B. g. miyakonis* from Miyakojima are shown in Figs. 1 and 2. Although there were minor differences, the basic structure of release calls was similar among three forms of Japanese toads examined as seen in the figures. Each important parameter of calls, i.e., number of notes per call, call duration, note duration, inter-note duration, note repetition rate, and dominant frequency, considerably varied within and among individuals according to their body size and/or body temperature. In a male *B. j. japonicus* from Takamatsu with SVL of 132.4 mm at 17.0°C BT (Fig. 1), the call duration was long, lasting about 3–5 sec. The calls consisted of 10–11 notes, and each note lasted about .08 sec with the interval of .15–.20 sec. The note repetition rate was about 3.9 per second. Within a single call, the duration of the first note was usually shorter than in the subsequent notes. The call typically could be divided into two phases. In the first phase, harmonic bands tended to be masked by many indistinct subbands, while in the second, clear harmonics were evident. Ten harmonic bands were apparent between 0–8 kHz, and average harmonic interval measured at the boundary of the first and second phases of a note was .77 kHz, which value corresponded to the fundamental frequency. The first dominant frequency was fundamental and the second corresponded to the ninth

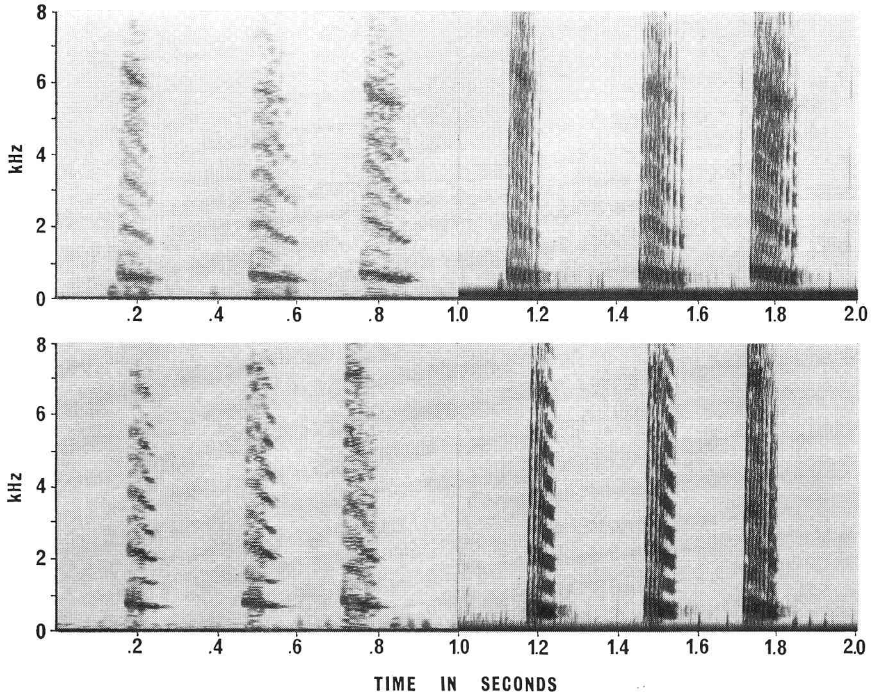

Fig. 1. A part of a release call of *B. japonicus formosus* from Kuramayama, Kyoto with SVL of 131.0 mm at 16.6°C BT (top) and of *B. j. japonicus* from Takamatsu with SVL of 132.4 mm at 17.0°C BT (bottom). Calls were analyzed with narrow (left) and wide (right) band filters.

harmonic of the spectrogram. The harmonic bands were almost constant or only slightly rose in frequency in the first phase and then declined towards the end of the note in the second phase. This frequency modulation was remarkable in the higher frequency bands than in the lower ones. Other individuals of *B. j. japonicus* and other subspecies or species exhibited similar basic characteristics in release calls, though the values of parameters varied as noted above.

Various body temperatures (8.5–26.5°C) affected two of three call parameters in each individual toad. Relationship of fundamental frequency and body temperature highly varied among individuals (Fig. 3). In some individuals, FF had a strongly positive correlation with BT ($r=.993$, $.005<p<.01$ in *B. j. formosus* from Iwakura, Kyoto; $r=.988$, $.005<p<.01$ in *B. j. japonicus* from Yakushima), but in others there was almost no correlation ($r=.099$, $p>.25$ in one *B. j. formosus* from Kuramayama, Kyoto). Therefore, FF was regarded as not affected by body temperature. By contrast, note duration had a significant negative correlation with BT ($p<.05$) in all individuals examined, and the increase of body temperature was regarded as invariably reducing duration of a note (Fig. 4). Note repetition rate had a strongly positive correlation with BT ($p<.005$) in many individuals and the increase of body temperature tended to cause the decrease of number of notes per second (Fig. 5). Even in individuals

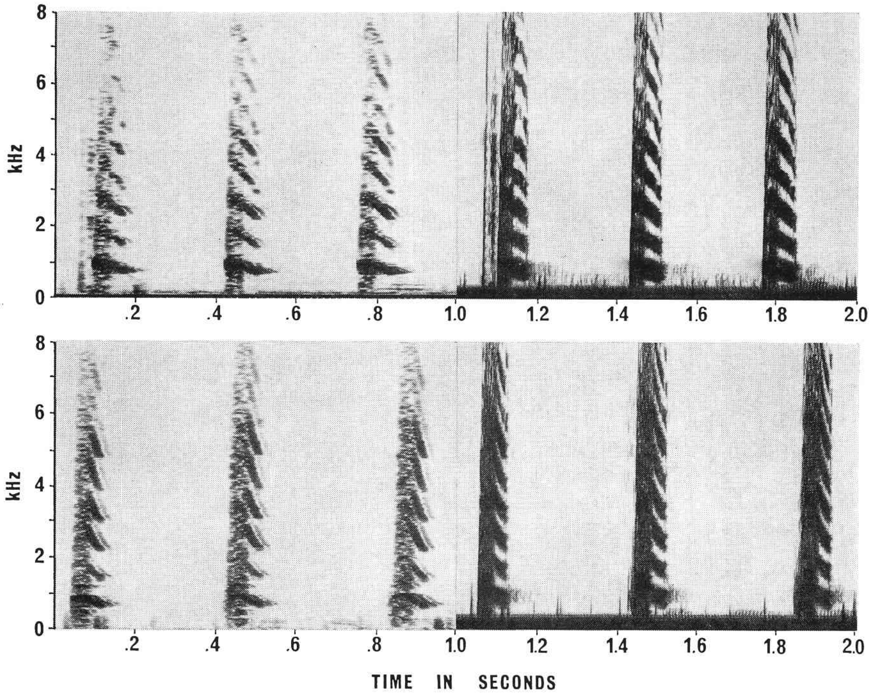

Fig. 2. A part of a release call of *B. j. japonicus* from Yakushima with SVL of 101.0 mm at 17.0°C BT (top) and of *B. gargarizans miyakonis* from Miyakojima with SVL of 92.0 mm at 17.0°C BT (bottom). Calls were analyzed with narrow (left) and wide (right) band filters.

with statistically insignificant correlations (one *B. j. formosus* from Kuramayama, Kyoto: r=.818; another *B. j. formosus* from Nogo Hakusan: r=.817), values of correlation coefficient were much higher than in the relation between BT and FF.

Regarding body temperature and call parameter relationships, similar results as above were obtained except for the relationship between FF and BT in *B. j. japonicus* from Takamatsu. Note duration markedly decreased with the increase of body temperature (Fig. 6), and the correlation (r=−.625) was highly significant ($p<.001$). This value of correlation coefficient was even higher than that obtained in the above result. Correlation of note repetition rate to body temperature (r=.788) was even higher ($p<<.001$), and the number of notes markedly increased with the increase of body temperature (Fig. 7). Fundamental frequency slightly decreased with the increase of body temperature, but the correlation (r=−.033) was not significant between these parameters ($P>.25$; Fig. 8).

The effect of body size (SVL) on each call parameter was somewhat different from that of body temperature. Fundamental frequency correlated negatively with SVL (r=−.415, p=.025; Fig. 9) and larger individuals emitted calls with lower frequencies. Larger individuals also tended to emit calls with longer notes, but correlation between SVL and note duration was low (r=.345) and statistically insig-

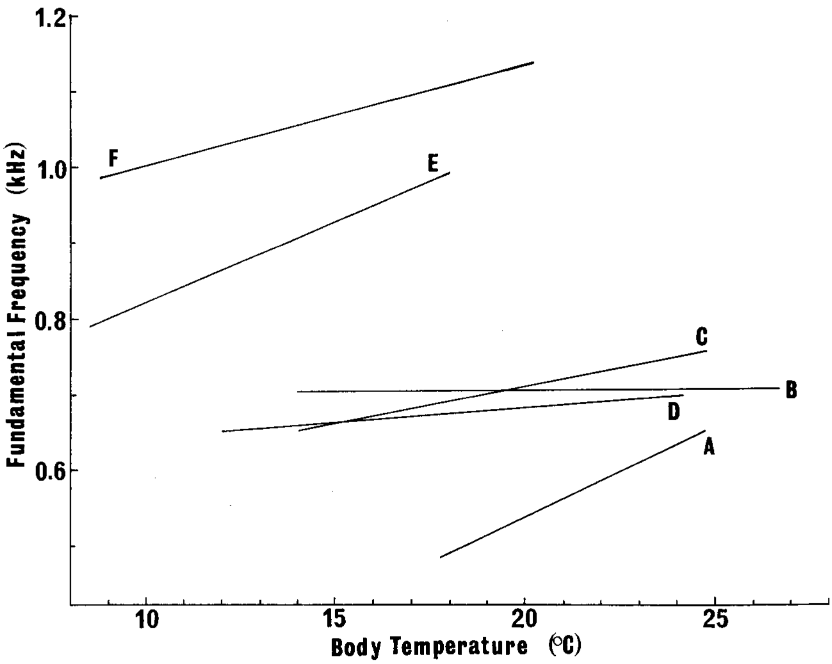

Fig. 3. The effect of temperature on fundamental frequency of the release call in six temperature-treated Japanese toads. A: *B. j. formosus* from Iwakura, Kyoto; B-C: *B. j. formosus* from Kuramayama, Kyoto; D: *B. j. formosus* from Nogo Hakusan; E: *B. j. japonicus* from Yakushima; F: *B. g. miyakonis* from Miyakojima. Regression equations fitted by the least squares method.

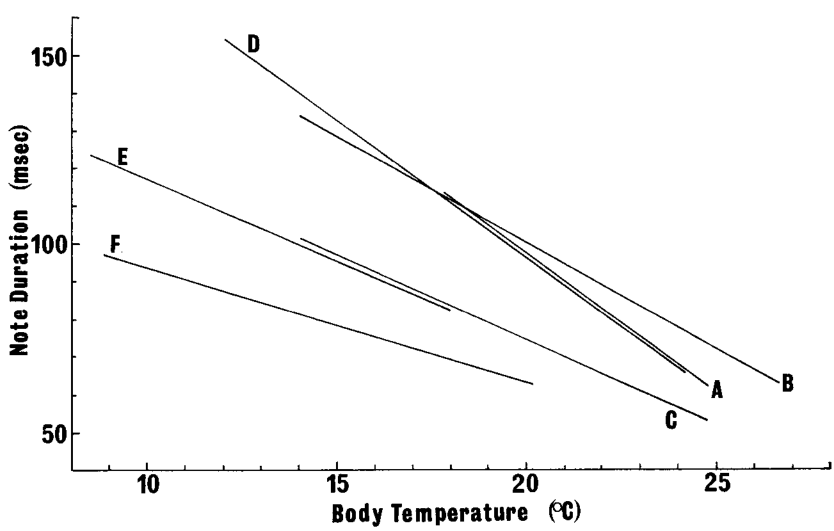

Fig. 4. The effect of temperature on note duration of the release call in six temperature-treated Japanese toads. A: *B. j. formosus* from Iwakura, Kyoto; B-C: *B. j. formosus* from Kuramayama, Kyoto; D: *B. j. formosus* from Nogo Hakusan; E: *B. j. japonicus* from Yakushima; F: *B. g. miyakonis* from Miyakojima. Regression equations fitted by the least squares method.

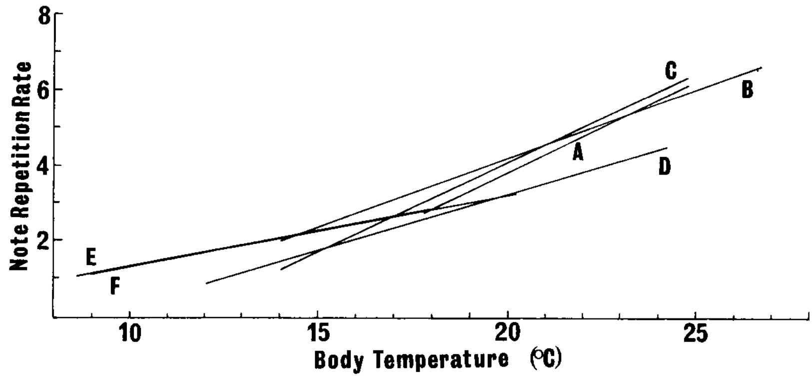

Fig. 5. The effect of temperature on note repetition rate of the release call in six temperature-treated Japanese toads. A: *B. j. formosus* from Iwakura, Kyoto; B-C: *B. j. formosus* from Kuramayama, Kyoto; D: *B. j. formosus* from Nogo Hakusan; E: *B. j. japonicus* from Yakushima; F: *B. g. miyakonis* from Miyakojima. Regression equations fitted by the least squares method.

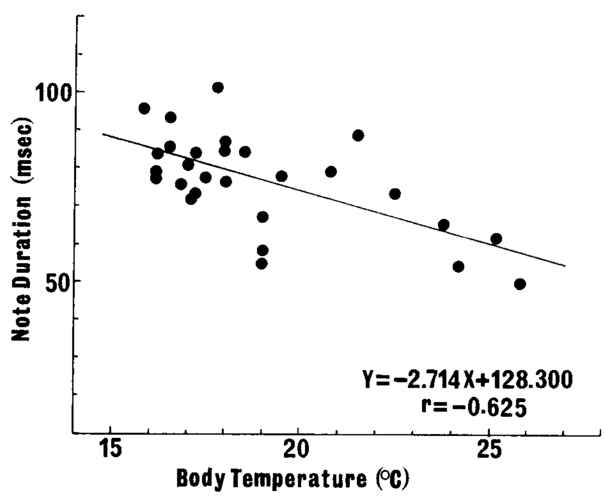

Fig. 6. The relationship between body temperature and note duration of the release call in *B. j. japonicus* from Takamatsu. Regression equation fitted by the least squares method.

nificant (.05<p<.1; Fig. 10). Note repetition rate had a strongly negative correlation with SVL (r=−.499, .01>p>.005; Fig. 11) and larger individuals emitted smaller number of notes per second compared with smaller individuals.

From these results, release calls of Japanese toads are predicted to be slower, more discontinuous and in a lower tone when emitted by larger individuals under lower temperatures, and conversely, continuous calls are predicted to be emitted more rapidly in a higher tone by smaller individuals under higher temperature conditions.

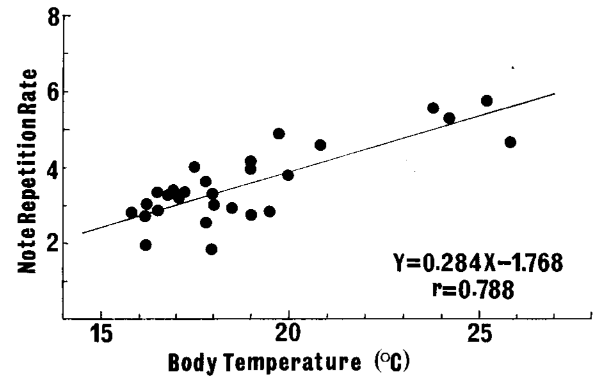

Fig. 7. The relationship between body temperature and note repetition rate of the release call in *B. j. japonicus* from Takamatsu. Regression equation fitted by the least squares method.

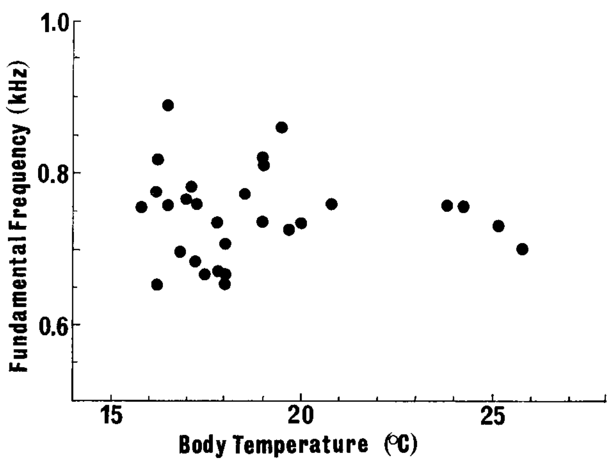

Fig. 8. The relationship between body temperature and fundamental frequency of the release call in *B. j. japonicus* from Takamatsu.

Discussion

The release calls of Japanese toads are basically similar to those reported for European *Bufo b. bufo* (Schneider, 1966 (originally reported as mating calls, but regarded as release calls by Heusser, 1969); Flindt and Hemmer, 1968; Heusser, 1970) in several diagnostic characteristics (e.g., a succession of short notes of similar pattern; presence of two distinct phases within a note; presence of clear harmonics declining towards the end of the note). The previous authors, however, gave no data about relationships between body temperature and/or body size and call parameters. The trends found in the release call characteristics of Japanese toads mainly agree to those of mating calls and release chirps in toads of other species group from North America (Zweifel, 1968; Brown and Littlejohn, 1972). Call parameters employed by Zweifel

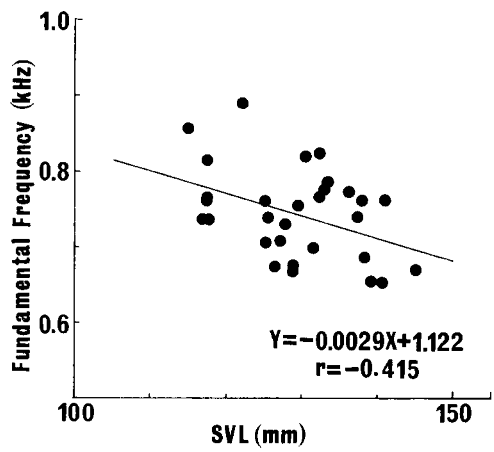

Fig. 9. The relationship between SVL and fundamental frequency of the release call in *B. j. japonicus* from Takamatsu. Regression equation fitted by the least squares method.

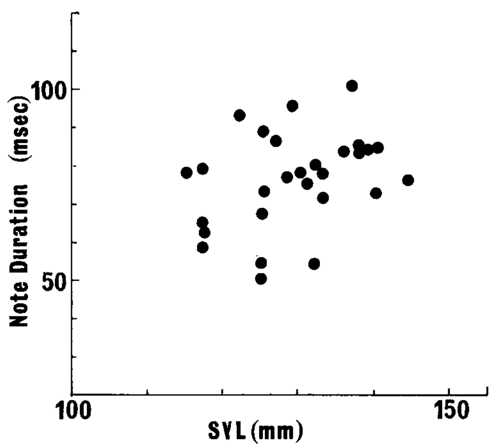

Fig. 10. The relationship between SVL and note duration of the release call in *B. j. japonicus* from Takamatsu.

(1968) for mating calls of *B. americanus* and *B. woodhousei fowleri* and Brown and Littlejohn (1972) for release chirps of the *B. americanus* group are different from those employed by me, but the call length and dominant frequency of these authors are comparable to note duration and fundamental frequency, respectively, of the present study. Especially, the fundamental strictly corresponds to the dominant frequency in release calls of Japanese toads as shown in the result. My results coincided with those of Brown and Littlejohn (1972) in the presence of negative correlations between SVL and frequency, and between temperature and duration, but differed from those of the latter authors in the absence of correlation between temperature and frequency. These authors, however, obtained highly variable results among species of the *B. americanus*

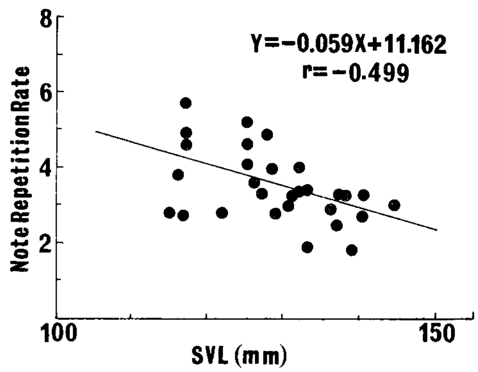

Fig. 11. The relationship between SVL and note repetition rate of the release call in *B. j. japonicus* from Takamatsu. Regression equation fitted by the least square method.

group, and they noted a reverse situation in the correlation of temperature to frequency between *B. woodhousei* and *B. houstonensis*. Zweifel (1968) also could detect significant correlation of temperature to frequency (of mating calls) only in half the populations he examined. In this way, it seems difficult at present to assess a universal trend about the relationships of temperature and body size to call parameters, but the results obtained by previous authors indicate that most of the relationships are in common within a species group of toads. Therefore, release call characteristics of Japanese toads here elucidated seem to apply to those of other forms of the *Bufo bufo* complex, and detailed comparisons among forms of this complex will be reported in future publications.

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